THE ABRADING AND TRANSPORTING POWER OF WATER

III.—PRACTICAL CONCLUSIONS

HAVING on two former occasions, when treating of the abrading and transporting power of water (which is supposed to increase as the velocity increases, but to decrease as the depth increases), dwelt on the mechanical property of water, and shown how it rolls rather than slides: the following conclusions may be arrived at:—

I. That all particles of water have an affinity to each other as well as to other bodies, and that force is required to separate them;

II. That friction sets these particles rotating in all directions in larger or smaller circles, and that the friction or force increases in some proportion to the area of surface exposed;

III. That this rolling motion becomes rarer the larger the diameter of the circles may be, that is, the resistance decreases as the depth and breadth of a stream increase, or in other words, the velocity increases proportionally to the "hydraulic mean depth;"

IV. Lastly, that any increase to the rapidity of this rotatory motion, must increase the abrading and transporting power of water, by enabling it to remove from the channel of a stream grains of solid matter, and hold them in suspension.

The following deductions are arrived at:—

1. That a smooth surface offers the smallest area for the water to attach itself to, and fewer irregularities; consequently the rotatory motion given to the water is reduced to a minimum, that is, the power expended is least, or the friction among the particles of water flowing through a smooth uniform channel is less than when it flows through an irregular and rough one.

2. That in the lines of a ship not only should there be no sudden changes in direction, but the surfaces should be as smooth as possible.

3. That the area of this surface should be as small as possible; hence convex lines are preferable to concave ones, as with the same area they afford greater buoyancy, while there would be less friction for the water to roll along a convex surface than a concave one.

4. That additional length given to a ship, leaving out all other questions, must retard a ship passing through the water, by increasing the area exposed to friction; consequently there is probably some limit owing to this increased resistance, where the length midships should not exceed certain proportions of the midship section.

5. That a ship passing over shallow water must be retarded, as the diameter of the vertical circles revolving under her bottom must be less than the diameter of the circles where the water is deep; hence the smaller circles will be set in quicker rotation, and therefore loss of power ensues.

6. That the same will be the effect from the same cause where the channel is narrow and contracted.

These deductions apply to cases where the abrasion may be considered "nil," such as the discharge of water through pipes, and the sailing of ships; and the practical conclusion is, that for pipes with glazed surfaces, and ships having coppered bottoms, the water passes with the least friction.[*] In the case of ships, *speed* is not the only question to be considered, so the subject becomes very complicated, and though believing in the general soundness of the above deductions, the solution of these problems may be left to the naval architect to consider.

Viewing the subject on the large scale, very important conclusions are arrived at from these facts—namely, that the depth of a river depends on the nature of the materials it has got to transport; thus those which have to carry down coarse sand should be broad and shallow, while those which have to convey fine mud would naturally be narrow and deep. And as this depends on the geological nature of the catchment basin of the river, are we not naturally led to the conclusion that where we find rivers navigable, the rocks of the catchment basin which predominate are of an aqueous formation, while those rivers which are difficult of approach from the sea must drain a country where crystalline rocks predominate? Judging, therefore, on this hypothesis, are we not right in conjecturing that the rocks of Central India, and also of that vast, but hitherto almost unexplored, country, Central Africa, must be generally of a crystalline nature?

This interesting question, however, like that of the best form of ships, had better be left for the consideration of the professional inquirer, whose investigations lead him to study that branch of geology which treats of the denudation of rocks now going on on the earth's crust, and the deposits now being formed. I pass on to those questions which affect the hydraulic engineer, and they are so numerous that it would be difficult even to enumerate and classify them, while their importance is so great that it can hardly be over-estimated. On this occasion only one or two of the more prominent subjects will be glanced at, more for the purpose of leading to future investigation, than to lay down rules for guidance, which at this present stage it would be premature to attempt.

From the foregoing remarks, suggestions, and deductions, it may be supposed that there are certain laws of nature which adapt each case to its own particular circumstances. Take, for example, the course of a river. It has been before said that streams which have to transport coarse, solid matter, such as sand, are usually broad and shallow, while those which convey chiefly fine mud are deep and narrow. The reason why those streams which convey a large proportion of sand should be broad and shallow, is that the water has thus sufficient power to hold the solid matter in suspension; and to still further aid them in this, it will be often observed that Nature generally gives such rivers comparatively speaking straight channels, in comparison to those which convey fine mud. The object in this case would appear to be that Nature in the former instance takes the shortest route, so as to obtain as great a fall as possible in the bed of the stream; while with the deep muddy stream, to prevent the water rushing off too fast, and so to keep up the surface of the stream to a level with the banks, or in floods often above them, Nature takes her tortuous courses, and is thus enabled year after year to deposit those fine grains of mud which add so much to the fertility of the soil.

So evidently is this the case, that in Egypt the irrigation canals are all carried in a zigzag direction, so as to check the velocity, and prevent the coarser particles of solid matter from being transported, while at the same time the surface of the water is kept at a sufficient elevation, so as to admit of easy irrigation. Thus, probably, Joseph, or whoever started irrigation in the land of the Pharaohs, took a leaf out of Nature's book; and it is by the study of this volume that the engineer of the present day will be most certain to arrive at satisfactory results.

That rivers have certain general principles by which they are governed, as to breadth, depth, slope, velocity, and load of solid matter held in suspension, it appears reasonable to suppose; and any change introduced in any

---

[*] On reading over the above conclusions to an experienced ship-builder here in London, he said that one of the reasons why Aberdeen clippers sailed so fast, was owing to the smoothness of the ships' bottoms, which were first planed before the copper was put on. He also remarked that where the copper is very smoothly put on, the first place where the sheet wears through is just behind where the sheets overlap, showing that even an irregularity of $\frac{1}{16}$ of an inch causes an extra action, not as might be supposed at the point of greatest obstruction, but just beyond it, proving that there must be this whirling motion which causes this abrasion. This gentleman also observed that experience showed that the speed of a ship chiefly depends on the fineness of the lines of the after rim of a ship, and that "ingoing" or concave lines should be avoided if possible.

© 1870 Nature Publishing Group

one of these proportions must cause a corresponding change in one or all of the above conditions.

Thus, let there be a stream which in flood contains 5 per cent. by weight of solid matter, and let it be 8 ft. deep, discharging 50,000 cubic feet a second, with a mean velocity of $7\frac{1}{2}$ ft. a second—the breadth of this stream would be $\frac{50{,}000}{8\times 7\cdot 5} = 833\frac{1}{3}$. To add one-fourth to the discharge of this stream of pure water would increase the discharge from 50,000 to 62,500 cubic feet a second, and the proportion of solid matter, instead of being 5 per cent., would be only 4 per cent. But, by the example before given, a depth approaching 9 ft. instead of 8 ft. would be the natural depth, so the bed would be lowered 1 ft., and the breadth would only be increased $\frac{12{,}500}{2\times 9\times 7\frac{1}{2}} = 92$ ft., instead of having to give an increase of one-fourth more, or $\frac{833}{4} = 208$ ft., and still keep matters much as they are found in nature.

So in bridging such a stream the whole additional length of viaduct would be only 92 ft., or 116 ft. would be saved by simply sinking the foundations 1 ft. more. But as water rolls rather than slides, and never flows in straight lines, the shape of the section of a stream can be changed at pleasure; so the depth may be increased without much danger by decreasing the breadth. Taking, then, the same stream which it was proposed to make $833 + 92 = 925$ ft. broad by 9 ft. deep, suppose the mean depth be made 15 ft., this increase of depth would decrease the transporting power, while at the same time the velocity would also be increased; and suppose it to be now 10 ft. a second, instead of $7\frac{1}{2}$ ft., and with a depth of 15 ft. with such a velocity only 4 per cent. of solid matter could be held in suspension, and the waterway would be $\frac{62{,}500}{15\times 10} = 416\frac{2}{3}$ ft. broad instead of 925 ft., or less than one-half. That is, by adding 8 ft. to the general depth of a stream where the river discharges 50,000 cubic feet a second in the main channel, and 12,500 cubic feet a second of inundation water, which is comparatively free of silt, the whole volume or 62,500 cubic feet could be passed through a bridge only half the breadth of the original stream, which was 833 ft. broad. So the whole question reduces itself now into one of cost.

The question is whether it be cheaper to sink the foundations an extra 8 or 10 ft., or to double the length of viaduct. By the use of the sand-pump foundations can now be sunk through sand at a very moderate cost; so it is believed that the extra sinking would not involve anything like the cost of the shallower foundations for the bridge built on the extended plan; thus the whole cost of the superstructure and extra girders could be saved—that is speaking approximately. In such a case the bridge built on this deep foundation principle could be built at nearly half the cost of the old plan; but to guard against accidents, and scooping out to excessive depths, it would appear that at least one-third may be saved by building bridges on this principle; while the river, by having a deep channel under the bridge, could be kept in better control than by the present extended method, as it would not have such a tendency to desert its course, but would always keep to the deep channel.

Several other examples may be brought forward to illustrate the practical advantages that a better knowledge of the action of flowing water would be sure to confer on science and hydraulic engineering; but it is hoped that the foregoing will assist in bringing the importance of the subject more prominently forward. When once the subject is properly discussed I am convinced its importance will be manifested.

T. LOGIN

SOCIETIES AND ACADEMIES

LONDON

Royal Society, May 19.—"Experiments on the Effects of Alcohol (*Ethyl Alcohol*) on the Human Body." By E. A. Parkes, M.D., F.R.S., Professor of Hygiene in the Army Medical School, and Count Cyprian Wollowicz, M.D., assistant-surgeon, Army Medical Staff.

"On Deep-sea Thermometers." By Staff-Commander John E. Davis, R.N. Communicated by Captain Richards, R.N., Hydrographer of the Admiralty. The results of thermometric observations at great depths in the ocean not being of a satisfactory nature, the attention of the hydrographer of the navy was directed to the defects in the construction of the Six's self-registering thermometers then in use, and also to the want of knowledge of the effects of compression on the bulb; and as it was known that a delicate thermometer was affected *in vacuo*, it was natural to suppose that an opposite effect would be had by placing them under pressure, and particularly such as they would be subjected to at great depths. Several thermometers, of a superior construction, were made by different makers, and permission was granted to make experiments by pressure in a hydraulic press; but much delay was caused by not being able to obtain a press suitable to the requirements, until Mr. Casella, the optician, had a testing-apparatus constructed at his own expense, and the experiments were commenced. Previous to the experiments being made, Dr. W. A. Miller, V.P.R.S., proposed, or rather revived, a mode of protecting the bulb from compression by encasing the full bulb in glass, the space between the case and the bulb being nearly filled with alcohol.* A wrought-iron bottle had been made to contain a thermometer, for the purpose of comparison with those subjected to compression; but it failed, and finally burst under great compression; it proved, however, of but little consequence, as those designed by Dr. Miller showed so little difference under pressure that they were at once accepted as standards. Two series of experiments were then most carefully made, at pressures equal to depths of 250, 500, &c., to 2,500 fathoms, the results of which satisfactorily proved that the strongest made unprotected thermometers were liable to considerable error, and therefore that all previous observations made with such instruments were incorrect. Experiments were also made in the testing-apparatus with Sir Wm. Thomson's enclosed thermometers, to ascertain the calorific effect produced by the sudden compression of water, in order to find what error, if any, was due to compression in the Miller pattern: an error was proved to exist, but small, amounting to no more than $1^\circ{\cdot}4$ under a pressure of 3 tons to the square inch. The dredging cruise of the *Porcupine* afforded an opportunity of comparing the results of the experiments made in the hydraulic testing apparatus, with actual observation in the ocean, and a most careful series of observations were obtained by Staff-Commander E. K. Calver at depths corresponding to the pressure applied in the testing apparatus; the result was that, although there was a difference in the curves drawn from the two modes of observation, still the general effect was the same, and the *means* of the two were identical. From these experiments and observations a scale has been made by which observations made by thermometers of similar construction to those with unprotected bulbs can be corrected and utilised, while it is proposed that by means of observations made with the Miller pattern in the positions and at the same depths at which observations have been made with instruments not now procurable for actual experiment, to form a scale for correcting all observations made with that particular type. In conclusion, it is suggested that to avoid error from the unsatisfactory working of the steel indices, which, from mechanical difficulties in their construction, cannot always be depended on, two instruments should be sent down for every observation; and although their occasional disagreement of record may raise a doubt, a little experience will enable the observer to detect the faulty indicator, while their agreement will create confidence.

London Mathematical Society, May 12.—Prof. Cayley, president, in the chair. The Hon. Sir J. Cockle, Chief Justice of Queensland, was proposed for election.—The President (Mr.

---

* *Vide* Proceedings of the Royal Society, vol. xvii. No. 113, June 17, 1869.

© 1870 Nature Publishing Group